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EXPERIMENTAL EFFORTS
TO AERATE THE AVON RIVER
WITH SMALL INSTREAM DAMS

Technical Report S-5

STRATFORD/AVON RIVER
ENVIRONMENTAL MANAGEMENT PROJECT

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Technical Report S-5

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Reference to equipment, brand names or supplies in this publication is not to be interpreted as an endorsement of that particular product or supplier.

PREFACE

This report is one of a series of technical reports resulting from work undertaken as part of the Stratford-Avon River Environmental Management Project (S.A.R.E.M.P.).

This two year project was initiated in April 1980, at the request of the City of Stratford. The S.A.R.E.M.P. is funded entirely by the Ontario Ministry of the Environment. The purpose of the project is to provide a comprehensive water quality management strategy for the Avon River basin. In order to accomplish this considerable investigation, monitoring and analysis has taken place. The outcome of these investigations and field demonstrations will be a documented strategy outlining the program and implementation mechanisms most effective in resolving the water quality problems now facing residents of the basin. The project is assessing urban, rural and in-stream management mechanisms for improving water quality.

This report results directly from the aforementioned investigations. It is meant to be technical in nature and not a statement of policy or program direction. Observations and conclusions are those of the author and do not necessarily reflect the attitudes or philosophy of all agencies and individuals affiliated with the project. In certain cases, the results presented are interim in nature and should not be taken as definitive until such time as additional support data are collected.

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ABSTRACT

As part of the Stratford-Avon River Environmental Management Project, the Water Resources Branch of the Ontario Ministry of the Environment carried out investigations on August 26-27, 1980 on the Avon River at a weir and a small rock dam at two separate locations to quantify the increase in dissolved oxygen (DO) due to aeration at the base of these dams. Further studies were carried out during the summer of 1981, in the Project's experimental reach, to test for aeration efficiency using four weir designs with a maximum height of 0.5 m. Data from these surveys were then used as input for the DOMOD3 DO-BOD model to predict how far downstream the effects of the dam and weirs would persist.

Survey results indicate that aeration is a function of height and turbulence. Since height is a limiting factor in the Avon River, because of the flat river banks, the 5-step design with a height of 0.5 m seems to be the best aerator for the Avon River. The modeling results indicate that the effects due to weir aeration persist from 43 m to 1281 m before DO drops below the Provincial Water Quality Objective of 47% saturation (approximately 4 mg/L minimum) and from 470 m to 1537 m before returning to background levels.

ACKNOWLEDGEMENTS

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1. INTRODUCTION

Water flowing over weirs or spillways of dams can be aerated or deaerated depending upon the ambient upstream dissolved oxygen (DO) concentrations in relation to air saturation concentration. When there is excessive plant and algal growth in a river and photosynthesis is taking place, DO levels can be elevated above saturation (supersaturation condition) and at night time, when there is no photosynthesis taking place, plants remove DO from the water for respiration. If river water is supersaturated and is allowed to flow over a dam, the effect of the dam is to deaerate it (towards saturation) and for the undersaturated condition, the effect is to aerate it. This natural phenomenom of aeration was considered of potential value to supplement sagging instream DO levels at night time in the Avon River. On August 26-27, 1980 studies were carried out on the Avon River at a weir at Station 6 and a small rock dam at Station 10 to quantify the increase in DO due to aeration at the base of these dams. Further studies were carried out in the experimental reach during the summer of 1981, to test for aeration efficiency using four weir designs (see Figure 4) with a maximum height of 0.5 m. Data from these surveys were then used to run the DOMOD3 model to predict how far downstream the effects of the dam persist. This report presents the findings of field and modelling investigations.

2. DESCRIPTION OF STUDY AREA AND DAMS

Figure 1 is a basin map showing the location of the weir at Station 6, the small rock dam at Station 10 and the site location of the experimental reach for the testing of the four weir designs.

The weir at Station 6 is located on the Avon River immediately upstream of John St. (see Figure 2). The weir is a broad-crested wooden structure 1.2 m high with vertical stop logs. A concrete walk-way extends from the right bank to approximately one third the width of the river. A concrete gate, 1.2m^2 has been incorporated into the supports of the walk-way at the far end and is kept open during winter months. At the base of the weir, there is a concrete apron and stilling basin.

The dam at Station 10 is a small broad-crested rock dam approximately 0.5 m high located on the Avon River (see Figure 3). The dam serves as a control for the federal government gauging station 02GD018 at Station 10.

The four experimental weirs were fabricated out of 3/4" plywood and 2" x 4" lumber. Drawings of these weirs are shown in Figure 4. The weirs were designed in such a manner that by adding 2 wooden blocks to the 3-step design, this weir was changed to a 5-step design and by taking the steps away, a single drop was left. Sandbags were used to constrict the flow to the width of the weir which was 1.2 m wide. The height of the weir after installation was 0.5 m. Figure 5 shows the 3-step design in place. Figure 6 shows the 3-step design looking downstream. Figure 7 shows the single drop and Figure 8 shows the sluice.

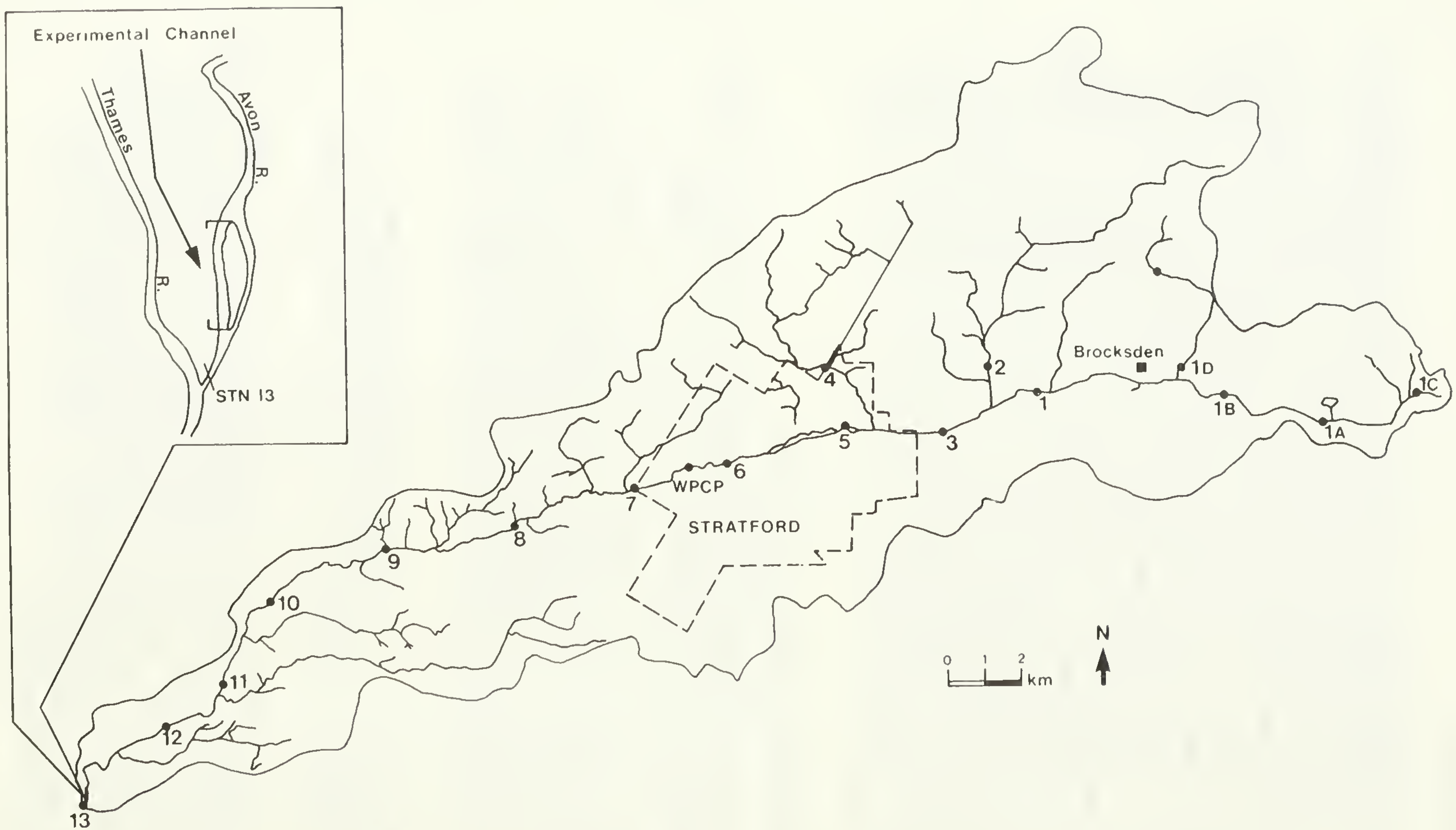


FIGURE 1: BASIN MAP SHOWING THE LOCATIONS OF WEIRS AT STATIONS 6 & 10 AND THE EXPERIMENTAL REACH

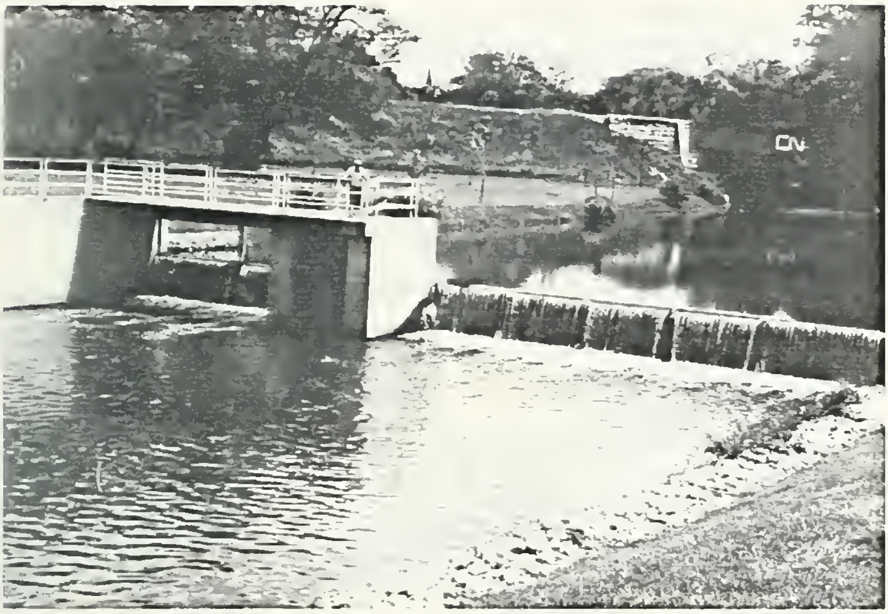
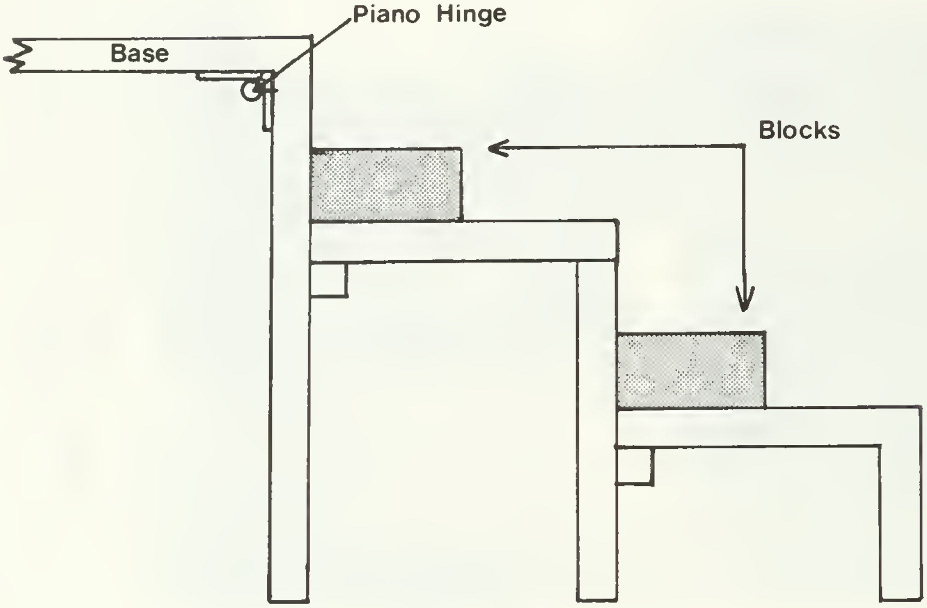


FIGURE 2: JOHN ST. WEIR - STATION 6

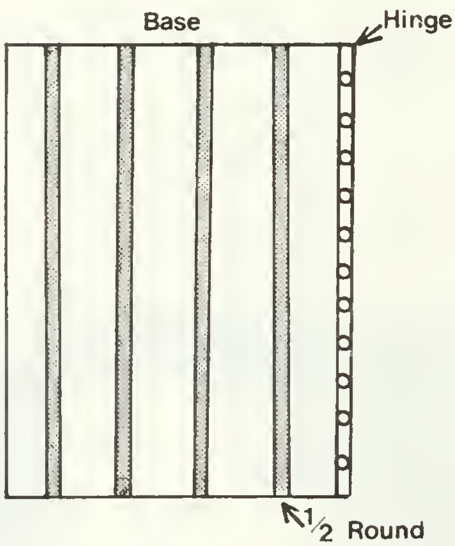
FIGURE 3: BROAD-CRESTED ROCK DAM AT STATION 10

FIGURE 4: EXPERIMENTAL WEIR DESIGNS

3 STEP DESIGN

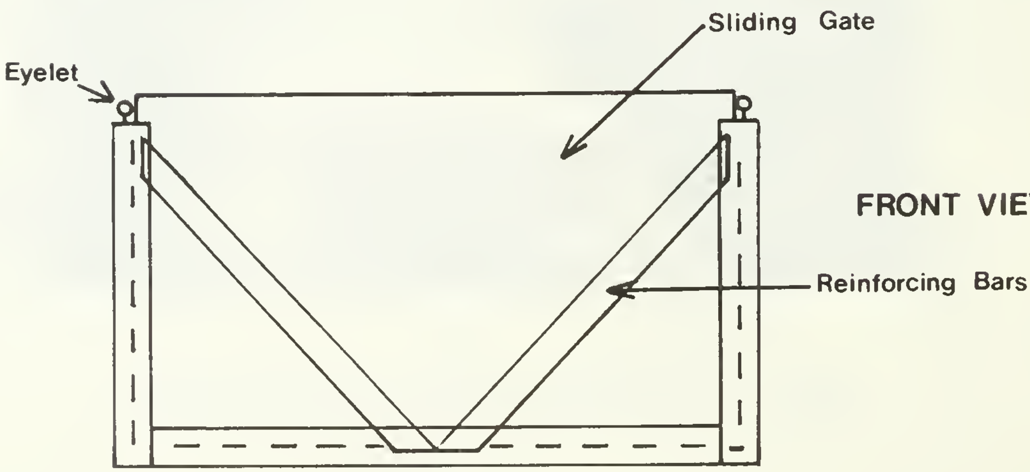


SIDE VIEW



TOP VIEW

SLUICE DESIGN



FRONT VIEW

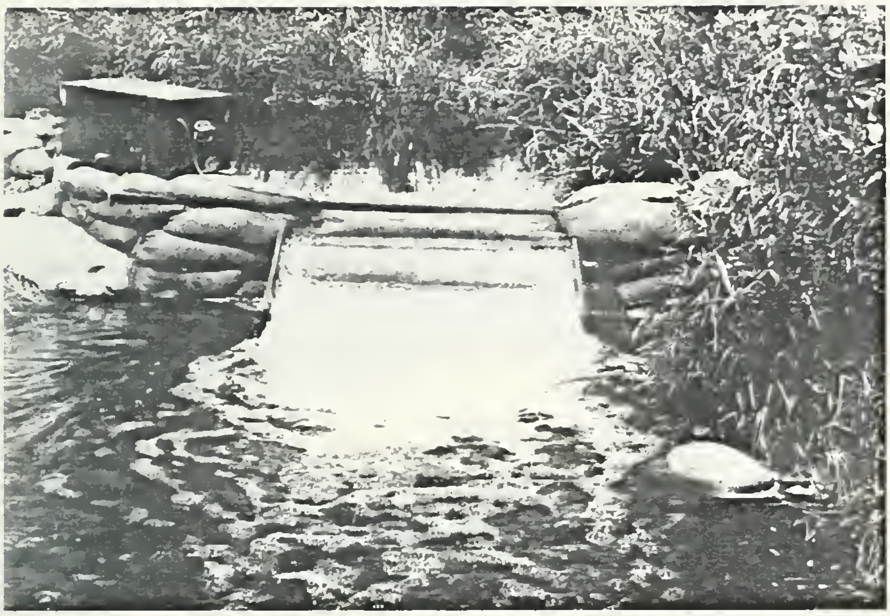


FIGURE 5: 3-STEP DESIGN WEIR

FIGURE 6: LOOKING DOWNSTREAM OF THE 3-STEP DESIGN WEIR

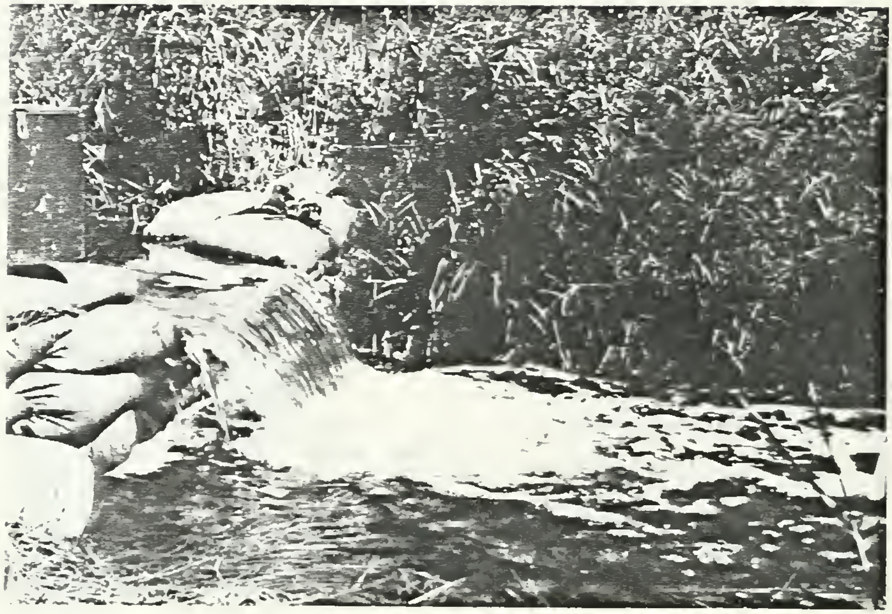


FIGURE 7: SINGLE DROP DESIGN WEIR

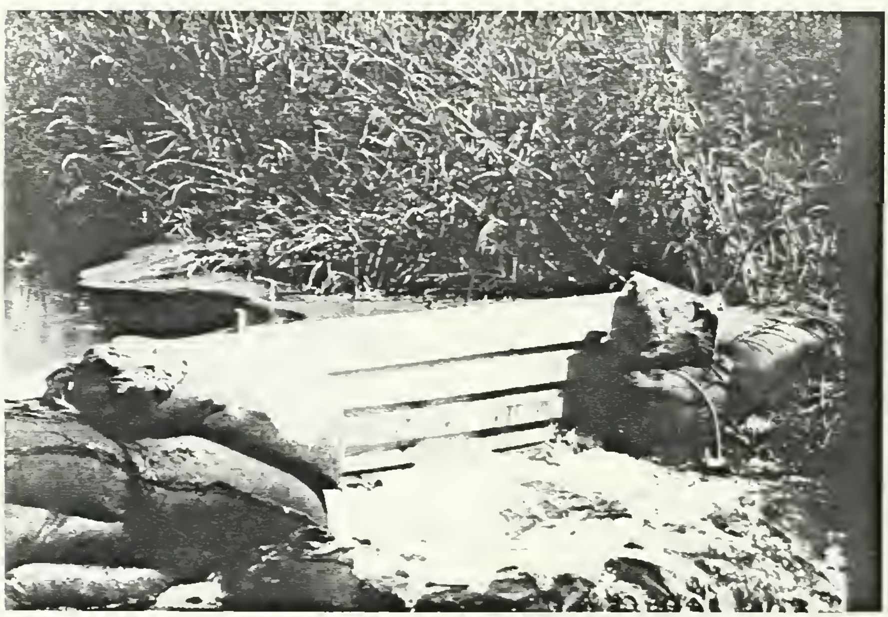


FIGURE 8: SLUICE

3. METHODS

Field work was conducted in August of 1980 and August and September of 1981. EIL meters with probes were connected to Rustrak recorders to monitor DO and temperature upstream and downstream of the dams at Stations 6 and 10, as well as in the experimental reach. Monitoring was conducted over a 24-hour period. DO deficits for both upstream and downstream reaches were calculated and a weir aeration coefficient (W) computed. Two methods of computation were used. The first was a direct estimate of weir aeration as the mean of aeration rates observed over the sample of hourly data for each weir. The second relied on regression analysis relating the change in the deficit to the initial deficit. W was then used to calculate the effect of the dam on the DO concentration from the following formula:

$$d_B = d_A\ (1-W)$$

where d_B = downstream DO deficit, mg/L
and d_A = upstream DO deficit, mg/L

Complete details for this type of investigation and criteria for selecting valid DO concentration data points are given in the report, Investigation of Weir Aeration and Sediment Oxygen Demand at Small Dams in the Grand River Basin, (Bacchus, River Systems File Report #RS-1, April 1980, Ontario Ministry of the Environment).

In order to predict how far downstream the effects of the weir persist, the DOMOD3 model was first run to depict a typical DO cycle and then with increases of 0.5, 1.0, 2.0 mg/L and 3.0 mg/L at an upstream node to represent the impact of weir aeration.

4. RESULTS

Detailed results from the field work and data analysis are presented in Table A1 to A12 of the Appendix. These results are summarized in Table 1 below.

The sluice design is not considered under 'Discussion' because the data revealed that the sluice had very little effect on the downstream DO concentrations. This was possibly due to an underdeveloped subcritical inflow. This condition, although it creates a hydraulic jump, is not as effective an aerator as a fully developed inflow which retains its air content longer than its underdeveloped counterpart.[1]

Plots of DO deficit decrease versus upstream DO deficit were prepared for each weir and are presented in Figures A1-A5. Results from the three experimental weirs and the John St. weir were used to model the downstream effects for Reach 9-10. The results show that with the single drop weir design, the maximum DO gained due to

(1) Markofsky, M. and Kobus, H., "Unified Presentation of Weir-Aeration Data", Journal of The Hydraulics Division, Technical Note 562, April 1978.

TABLE 1: SUMMARY OF WEIR AERATION DATA AND COMPUTATIONS

Weir Description	Upstream DO (mg/L)		Observed Data Downstream DO (mg/L)		Temperature ^0C		Observed Aeration Rate *(%)			External Aeration Rate by Regression* (%)
	max	min	max	min	max	min	mean	max	min	
single step (1.2 m) at Station 6	14.13	10.84	9.76	8.46	22.8	22.0	88	100	73	88
rock dam at Station 10	16.12	3.26	15.90	4.20	27.9	21.3	7	43	0	14
Experimental Reach Weirs:										
sluice	16.30	5.94	17.32	5.99	21.8	16.4	5	30	0	n.a.**
single step (.5 m)	16.03	4.91	15.32	5.28	25.4	17.4	12	50	3	8
3-step (.5 m)	15.60	4.57	13.69	5.44	28.6	20.9	34	77	22	26
5-step (.5 m)	14.44	3.09	13.10	5.00	25.0	17.4	25	58	2	19

* Expressed as percent reduction of deficit.
** Not applicable, coefficient estimated by regression had the wrong sign.

aeration is 0.5 mg/L and the effects last for 43 m before it reverts to the Provincial Water Quality Objective (PWQO) of 4 mg/L and 470m before it returns to the background level. Table 2 gives a summary of maximum DO gained for each weir design and the time and distance downstream before the DO reverts to the PWQO and the background level, respectively. Figures 9 and 10 compare the efficiency of each type of weir over the base case.

TABLE 2: SUMMARY OF MAXIMUM DO GAINED FOR EACH WEIR DESIGN AND TIME AND DISTANCE DOWNSTREAM OF WEIR FOR DO TO RETURN TO PWQO AND BACKGROUND LEVELS

Type of Weir	Max. DO Gained Due to Weir Aeration (mg/L)	PWQO		Background	
		Time (hrs)	Distance (m)	Time (hrs)	Distance (m)
Single Drop (0.5m)	0.5	0.1	43	1.1	470
Single Drop (1.2m)	3.0	3.0	1281	3.6	1537
3-Step Design	1.0	1.05	448	2.0	854
5-Step Design	2.0	2.17	926	2.9	1238

FIGURE 9: MINIMUM DO PROFILE FOR BASE CASE AND 2 SINGLE DROP WEIRS OF DIFFERENT HEIGHTS FOR REACH 9-10

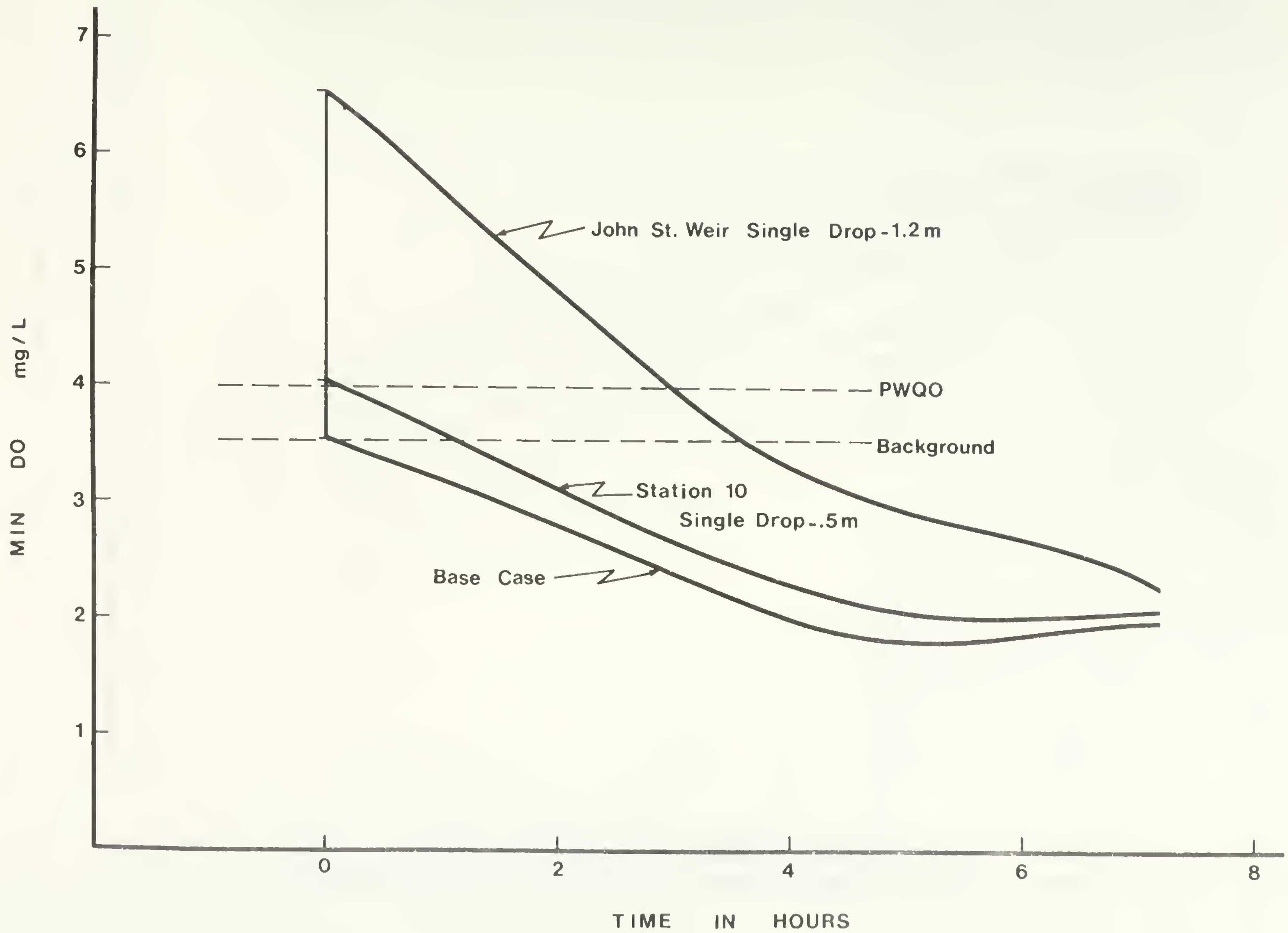
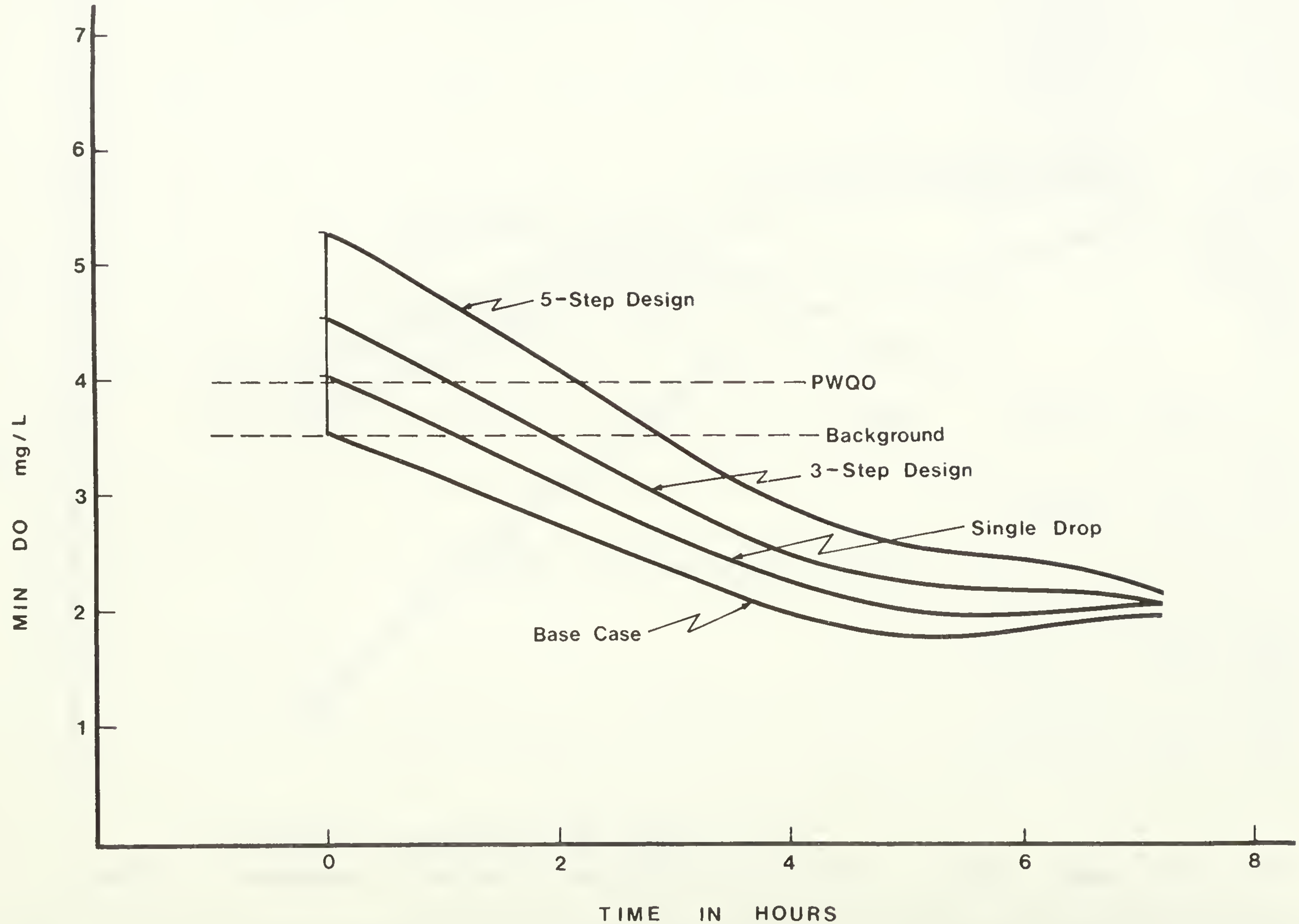


FIGURE 10: MINIMUM DO PROFILE FOR BASE CASE, SINGLE DROP, 3-STEP DESIGN AND 5-STEP DESIGN FOR REACH 9-10



DISCUSSION

From Table 1 it can be seen that with the single drop (0.5m), it is possible to gain a maximum of 0.5 mg/L. However, if a comparison is made between this weir and the John St. weir which has a single drop of 1.2m, it is possible to gain as much as 3.0 mg/L. It can also be seen from Table 1, that efficiency of the gas transfer process increases with the number of times water falls before coming to rest in the stilling pool. In technical note #13651, Unified Presentation of Weir-Aeration Data, Journal of the Hydraulics Division, April 1978, Mark Markofsky and Helmut Kobus state that efficiency of the gas transfer process increases with the height of fall and an increase in flow rate because air is entrained to greater depths, and, with increasing turbulence in the plunge pool, because air is broken into finer and finer bubbles. This verifies the findings of the writer. From these data, it is possible to estimate the number of weirs required to keep the DO above the PWQO during periods of low DO. However, if this data is to be extrapolated to other reaches, the effectiveness of the weirs and consequently the total number required will depend on the atmospheric reaeration rate (K_2) and other rates assumed for the other reaches. For reach 9-10, if the 5-step design is selected, then 3 weirs of this type are required to keep the DO above the PWQO.

CONCLUSIONS

(1) Weirs can act as effective low cost mechanisms for promoting gas transfer.

(2) Aeration efficiency depends on the height of weir and the number of times water falls before coming to rest in a plunge pool. In the Avon River, height is a limiting factor and should not generally exceed 0.5 m (see Report S-2). The 5-step design with a height of 0.5 m seems to be the best aerator of the designs tested.

(3) Three weirs would be required to keep the DO above the PWQO on Reach 9-10. The total number for the Avon River to keep the DO above the PWQO depends on K_2 and other rates selected for the other reaches.

APPENDIX

TABULATIONS AND FIGURES

TABLE A1: STATION 6 - FIELD SURVEY DATA

Date	Time	Temp. (°C)	Upstream (CA) DO (mg/L)	Downstream (CB) DO (mg/L)	Sat. DO (mg/L)
Aug. 26/80	16:00	22.8	11.32	9.06	8.71
	17:00	22.8	13.07	9.41	8.71
	18:00	22.8	13.24	9.76	8.71
	19:00	22.8	14.02	9.76	8.71
	20:00	22.7	14.13	9.68	8.72
	21:00	22.5	13.91	9.45	8.75
	22:00	22.5	13.83	9.19	8.75
	23:00	22.4	13.68	9.03	8.77
Aug. 27/80	0:00	22.3	13.61	8.87	8.78
	1:00	22.4	13.33	8.77	8.77
	2:00	22.2	13.02	8.62	8.80
	3:00	22.1	12.69	8.46	8.81
	4:00	22.0	12.72	8.48	8.83
	5:00	22.0	12.36	8.57	8.83
	6:00	22.1	12.07	8.63	8.81
	7:00	22.0	11.92	8.65	8.83
	8:00	22.0	12.01	8.83	8.83
	9:00	22.0	12.45	8.92	8.83
	10:00	22.0	12.80	8.92	8.83
	11:00	22.2	11.97	9.15	8.80
	12:00	22.5	12.25	9.19	8.75
	13:00	22.5	11.90	9.10	8.75
	14:00	22.6	10.84	9.09	8.74
	15:00	22.7	11.51	9 16	8.72
	16:00	22.8	12.28	9.67	8.71

TABLE A2: CALCULATION OF WEIR AERATION COEFFICIENT AT STATION 6

Time	d_A	d_B	$d_A - d_B$	$W = (d_A - d_B)/d_A$	Remarks
16:00	-2.57	-0.35	-2.22	0.86	
17:00	-4.32	-0.70	-3.62	0.84	
18:00	-4.49	-1.05	-3.44	0.77	
19:00	-5.27	-1.05	-4.22	0.80	
20:00	-5.41	-0.96	-4.45	0.82	
21:00	-5.16	-0.70	-4.46	0.86	
22:00	-5.08	-0.44	-4.64	0.91	
23:00	-4.91	-0.26	-4.65	0.95	
0:00	-4.83	-0.09	-4.74	0.98	
1:00	-4.56	-0.00	-4.56	1.00	
2:00	-4.22	+0.18	--	--	a (see criteria table below)
3:00	-3.88	+0.35	--	--	a (see criteria table below)
4:00	-3.89	+0.35	--	--	a (see criteria table below)
5:00	-3.53	+0.26	--	--	a (see criteria table below)
6:00	-3.26	+0.18	--	--	a (see criteria table below)
7:00	-3.09	+0.18	--	--	a (see criteria table below)
8:00	-3.18	-0.00	-3.18	1.00	
9:00	-3.62	-0.09	-3.53	0.98	
10:00	-3.97	-0.09	-3.88	0.98	
11:00	-3.17	-0.35	-2.82	0.89	
12:00	-3.50	-0.44	-3.06	0.87	
13:00	-3.15	-0.35	-2.80	0.89	
14:00	-2.10	-0.35	-1.75	0.83	
15:00	-2.79	-0.44	-2.35	0.84	
16:00	-3.57	-0.96	-2.61	0.73	

Criteria for Omitting Data

a - CA & CB $\nless$ CS; CB $\geq$ CA
b - CA < CS; CB $\leq$ CS
c - CA & CB > CS; CB $\leq$ CA
d - CA > CS; CB $\geq$ CS

Mean Coefficient, W = 0.88

TABLE A3: STATION 10 - FIELD SURVEY DATA

Date	Time	Temp. (^{o}C)	Upstream (CA) DO (mg/L)	Downstream (CB) DO (mg/L)	Sat. DO (mg/L)
Aug. 26/80	14:00	24.9	11.91	11.49	8.39
	15:00	25.8	14.52	13.28	8.25
	16:00	26.9	16.00	14.14	8.08
	17:00	27.5	--	15.66	7.99
	18:00	27.8	--	15.90	7.95
	19:00	27.9	--	15.86	7.93
	20:00	27.6	16.12	15.56	7.98
	21:00	27.3	13.63	13.63	8.02
	22:00	27.2	9.89	10.13	8.04
	23:00	27.0	7.10	7.51	8.07
	24:00	25.4	5.74	6.16	8.32
Aug. 27/80	1:00	24.7	4.63	5.39	8.42
	2:00	24.1	3.91	4.60	8.31
	3:00	23.5	3.53	4.39	8.60
	4:00	23.1	3.38	4.24	8.66
	5:00	22.5	3.33	4.20	8.75
	6:00	22.2	3.26	4.22	8.80
	7:00	21.8	3.28	4.25	8.86
	8:00	21.4	3.48	4.29	8.93
	9:00	21.3	3.93	4.47	8.94
	10:00	21.6	5.42	5.42	8.89
	11:00	22.2	7.39	7.04	8.80
	12:00	23.3	9.84	9.32	8.63
	13:00	24.6	12.24	11.39	8.44
	14:00	25.7	13.81	12.90	8.27

TABLE A4: CALCULATION OF WEIR AERATION COEFFICIENT FOR SMALL DAM AT STATION 10

Time	d_A	d_B	d_A-d_B	W = $(d_A-d_B)/d_A$	Remarks
14:00	-3.52	-3.10	-0.41	0.12	
15:00	-6.27	-5.03	-1.24	0.20	
16:00	-7.92	-6.06	-1.86	0.23	
17:00	--	-7.67	--	--	(incomplete data)
18:00	--	-7.95	--	--	(incomplete data)
19:00	--	-7.93	--	--	(incomplete data)
20:00	-8.14	-7.58	-0.56	0.07	
21:00	-5.61	-5.61	0.00	0.00	
22:00	-1.85	-2.09	0.24	--	c (see criteri table below)
23:00	0.97	0.56	0.41	0.42	
24:00	2.58	2.16	0.42	0.16	
1:00	3.79	3.03	0.76	0.20	
2:00	4.40	3.71	0.69	0.16	
3:00	5.07	4.21	0.86	0.17	
4:00	5.28	4.42	0.86	0.16	
5:00	5.42	4.55	0.87	0.16	
6:00	5.54	4.58	0.96	0.17	
7:00	5.58	4.61	0.97	0.17	
8:00	5.45	4.64	0.81	0.15	
9:00	5.01	4.47	0.54	0.11	
10:00	3.47	3.47	0.00	0.00	
11:00	1.41	1.76	-0.35	--	a (see criteria table below)
12:00	-1.21	-0.69	-0.52	0.43	
13:00	-3.80	-2.95	-0.85	0.22	
14:00	-5.54	-4.63	-0.91	0.16	

Criteria for Omitting Data

a - CA & CB < CS; CB ≥ CA
b - CA < CS; CB ≤ CS
c - CA & CB > CS; CB ≤ CA
d - CA > CS; CB ≥ CS

Mean Coefficient, W = 0.17

TABLE A5: 3-STEP WEIR - FIELD SURVEY DATA

Date	Time	Temp. (^{o}C)	Upstream (CA) DO (mg/L)	Downstream (CB) DO (mg/L)	Sat. DO (mg/L)
Aug./81	14:00	27.1	14.85	12.79	8.07
	15:00	28.0	15.05	13.14	7.92
	16:00	28.6	14.87	13.31	7.83
	17:00	28.6	14.41	10.49	7.83
	18:00	28.3	13.30	9.07	7.87
	19:00	27.9	11.42	7.56	7.93
	20:00	27.3	8.98	6.35	8.02
	21:00	26.5	6.84	5.84	8.14
	22:00	25.8	5.45	5.57	8.25
	23:00	24.8	4.79	5.44	8.41
	24:00	24.1	4.61	5.48	8.53
	1:00	23.4	4.57	5.51	8.62
	2:00	22.8	4.62	5.56	8.71
	3:00	22.3	4.74	5.75	8.78
	4:00	22.0	4.86	5.86	8.83
	5:00	21.4	5.18	5.98	8.93
	6:00	21.0	5.30	6.17	8.99
	7:00	20.9	5.50	6.55	9.01
	8:00	20.9	6.31	7.27	9.01
	9:00	21.4	7.50	8.54	8.93
	10:00	22.0	9.89	10.28	8.83
	11:00	23.3	12.43	11.14	8.63
	12:00	24.8	14.30	12.69	8.41
	13:00	26.3	15.36	13.07	8.17
	14:00	27.7	15.60	13.69	7.96

TABLE A6: CALCULATION OF WEIR AERATION COEEFICIENT FOR 3-STEP WEIR

Time	d_A	d_B	$d_A - d_B$	$W = (d_A - d_B)/d_A$	Remarks
14:00	-6.78	-4.71	-2.07	+0.30	
15:00	-7.13	-5.07	-2.06	+0.29	
16:00	-7.04	-5.39	-1.65	+0.23	
17:00	-6.58	-2.66	-3.92	+0.60	
18:00	-5.43	-1.24	-4.19	+0.77	
19:00	-3.49	+0.31	--	--	a (see criteria table below)
20:00	-0.96	+1.58	--	--	a (see criteria table below)
21:00	+1.30	+2.18	--	--	a (see criteria table below)
22:00	+2.80	+2.57	--	--	a (see criteria table below)
23:00	+3.62	+2.81	+0.81	+0.22	
24:00	+3.92	+2.93	+0.99	+0.25	
1:00	+4.05	+3.02	+1.03	+0.25	
2:00	+4.09	+3.06	+1.03	+0.25	
3:00	+4.04	+2.96	+1.08	+0.27	
4:00	+3.97	+2.92	+1.05	+0.26	
5:00	+3.75	+2.85	+0.90	+0.24	
6:00	+3.69	+2.76	+0.93	+0.25	
7:00	+3.51	+2.44	+1.07	+0.30	
8:00	+2.70	+1.74	+0.96	+0.36	
9:00	+1.43	+0.47	+0.96	+0.67	
10:00	-1.06	-1.35	--	--	c (see criteria table below)
11:00	-3.80	-2.31	-1.49	+0.39	
12:00	-5.89	-4.06	-1.83	+0.31	
13:00	-7.19	-4.66	-2.53	+0.35	
14:00	-7.64	-5.52	-2.12	+0.28	

Criteria for Omitting Data

- a - CA & CB $<$ CS; CB $\geq$ CA
- b - CA $<$ CS; CB $\leq$ CS
- c - CA & CB $>$ CS; CB $\leq$ CA
- d - CA $>$ CS; CB $\geq$ CS

Mean Coefficient, W = 0.34

TABLE A7: 5-STEP WEIR - FIELD SURVEY DATA

Date	Time	Temp. (^{o}C)	Upstream (CA) DO (mg/L)	Downstream (CB) DO (mg/L)	Sat. DO (mg/L)
Aug. 17/81	12:45	21.0	13.93	12.6	8.99
	13:45	22.5	14.44	13.2	8.75
	14:45	23.7	14.40	13.1	8.57
	15:45	24.7	14.15	12.8	8.42
	16:45	25.0	13.58	12.1	8.38
	17:45	24.3	12.21	10.8	8.48
	18:45	23.2	10.90	9.6	8.65
	19:45	22.7	9.50	8.6	8.72
	20:45	20.8	8.22	7.4	9.03
	21:45	20.4	6.73	6.2	9.10
	22:45	20.0	5.41	5.5	9.17
	23.45	19.6	4.62	5.1	9.24
Aug. 18/81	0:45	19.7	4.24	5.0	9.22
	1:45	19.2	3.91	5.0	9.31
	2:45	18.6	3.58	5.0	9.43
	3:45	17.4	3.09	5.2	9.66

TABLE A8: CALCULATION OF WEIR AERATION COEEFICIENT FOR 5-STEP WEIR

Time	d_A	d_B	$d_A - d_B$	$W = (d_A - d_B)/d_A$	Remarks
12:45	-4.94	-3.61	-1.33	+0.27	
13:45	-5.69	-4.45	-1.24	+0.22	
14:45	-5.83	-4.53	-1.30	+0.22	
15:45	-5.73	-4.38	-1.35	+0.24	
16:45	-5.20	-3.72	-1.48	+0.28	
17:45	-3.73	-2.32	-1.41	+0.38	
18:45	-2.25	-0.95	-1.30	+0.58	
19:45	-0.78	+0.12	--	--	a (see criteria table below)
20:45	-0.81	+1.63	--	--	a (see criteria table below)
21:45	+0.37	+2.90	--	--	a (see criteria table below)
22:45	+3.76	+3.67	+0.09	+0.02	
23:45	+4.62	+4.14	+0.48	+0.10	
0:45	+4.98	+4.22	+1.76	+0.15	
1:45	+5.40	+4.31	+1.09	+0.20	
2:45	+5.85	+4.43	+1.42	+0.24	
3:45	+6.57	+4.46	+2.11	+0.32	

Criteria for Omitting Data

a - CA & CB < CS; CB ≥ CA
b - CA < CS; CB ≤ CS
c - CA & CB > CS; CB ≤ CA
d - CA > CS; CB ≥ CS

Mean Coefficient, W = 0.25

TABLE A9: SINGLE DROP WEIR - FIELD SURVEY DATA

Date	Time	Temp. (^{o}C)	Upstream (CA) DO (mg/L)	Downstream (CB) DO (mg/L)	Sat. DO (mg/L)
Aug. 18/81	12.35	22.3	15.19	13.83	8.78
	13:35	23.4	15.69	14.74	8.62
	14:35	24.3	15.69	14.85	8.48
	15:35	25.0	15.42	14.86	8.38
	16:35	25.4	14.48	14.31	8.32
	17:35	25.1	12.62	12.69	8.36
	18:35	24.8	11.02	11.45	8.41
	19:35	24.2	9.40	10.01	8.50
	20:35	23.5	8.26	8.43	8.60
	21:35	22.7	6.54	6.97	8.72
	22:35	21.8	5.49	5.98	8.86
	23:35	21.0	5.03	5.54	8.99
Aug. 19/81	0:35	20.1	4.94	5.42	9.15
	1:35	19.5	4.91	5.28	9.26
	2:35	19.0	5.05	5.34	9.35
	3:35	18.6	5.09	5.56	9.43
	4:35	18.2	5.61	5.88	9.50
	5:35	18.0	5.82	6.00	9.54
	6:35	17.7	5.86	6.10	9.60
	7:35	17.4	6.47	6.60	9.66
	8:35	17.5	8.29	7.90	9.64
	9:35	18.0	10.49	10.28	9.54
	10:35	19.2	12.66	12.38	9.31
	11:35	20.6	14.50	13.85	9.06
	12:35	22.2	15.49	14.95	8.80
	13:35	23.5	16.03	15.32	8.62

TABLE A10: CALCULATION OF WEIR AERATION COEEFICIENT FOR SINGLE DROP WEIR

Time	d_A	d_B	$d_A - d_B$	$W = (d_A - d_B)/d_A$	Remarks
12:35	-6.41	-5.05	-1.36	+0.21	
13:35	-7.07	-6.12	-0.95	+0.13	
14:35	-7.21	-6.37	-0.84	+0.12	
15:35	-7.04	-6.48	-0.56	+0.08	
16:35	-6.16	-5.99	-0.17	+0.03	
17:35	-4.26	-4.33	--	--	c (see criteria table below)
18:35	-2.61	-3.04	--	--	c (see criteria table below)
19:35	-0.90	-1.51	--	--	c (see criteria table below)
20:35	+0.34	+0.17	+0.17	+0.50	
21:35	+2.18	+1.75	+0.43	+0.20	
22:35	+3.37	+2.88	+0.49	+0.15	
23:35	+3.96	+3.45	+0.51	+0.13	
0:35	+4.21	+3.73	+0.48	+0.11	
1:35	+4.35	+3.98	+0.37	+0.08	
2:35	+4.30	+4.01	+0.29	+0.07	
3:35	+4.34	+3.87	+0.47	+0.11	
4:35	+3.89	+3.62	+0.27	+0.07	
5:35	+3.72	+3.54	+0.18	+0.05	
6:35	+3.74	+3.50	+0.24	+0.06	
7:35	+3.19	+3.06	+0.13	+0.04	
8:35	+1.35	+1.74	--	--	a (see criteria table below)
9:35	-0.95	-0.74	-0.21	+0.22	
10:35	-3.35	-3.07	-0.28	+0.08	
11:35	-5.44	-4.79	-0.65	+0.12	
12:35	-6.69	-6.15	-0.54	+0.08	
13:35	-7.41	-6.70	-0.71	+0.10	

Criteria for Omitting Data

a - CA & CB < CS; CB ≥ CA
b - CA < CS; CB ≤ CS
c - CA & CB > CS; CB ≤ CA
d - CA > CS; CB ≥ CS

Mean Coefficient, W = 0.12

TABLE A11: SLUICE - FIELD SURVEY DATA

Date	Time	Temp. (^oC)	Upstream (CA) DO (mg/L)	Downstream (CB) DO (mg/L)	Sat. DO (mg/L)
Sept./81	18:00	21.8	14.80	15.33	8.86
	19:00	21.2	12.54	12.99	8.96
	20:00	20.7	9.49	10.49	9.04
	21:00	20.2	8.22	8.49	9.13
	22:00	19.6	7.30	7.39	9.24
	23:00	19.3	6.70	6.79	9.30
	24:00	18.9	6.28	6.37	9.37
	1:00	18.3	6.07	6.16	9.48
	2:00	18.0	6.01	6.11	9.54
	3:00	17.8	5.94	6.04	9.58
	4:00	17.6	5.96	6.06	9.62
	5:00	17.4	5.99	5.99	9.66
	6:00	17.3	6.00	6.00	9.68
	7:00	16.9	6.05	6.05	9.76
	8:00	16.7	6.37	6.47	9.80
	9:00	16.4	8.09	8.29	9.87
	10:00	16.6	10.11	10.41	9.82
	11:00	17.5	12.24	12.92	9.64
	12:00	18.2	14.73	15.77	9.50
	13:00	18.8	15.68	16.71	9.39
	14:00	19.0	15.90	17.11	9.35
	15:00	19.5	16.30	17.32	9.26
	16:00	19.5	15.74	16.67	9.26
	17:00	19.0	14.59	15.33	9.35

TABLE A12: CALCULATION OF WEIR AERATION COEEFICIENT FOR SLUICE

Time	d_A	d_B	$d_A - d_B$	$W = (d_A-d_B)/d_A$	Remarks
18:00	-5.94	-6.47	--	--	c (see criteria table below)
19:00	-3.58	-4.03	--	--	c (see criteria table below)
20:00	-0.45	-1.45	--	--	c (see criteria table below)
21:00	+0.91	+0.64	+0.27	+0.30	
22:00	+1.94	+1.85	+0.09	+0.05	
23:00	+2.60	+2.51	+0.09	+0.04	
24:00	+3.09	+3.00	+0.09	+0.03	
1:00	+3.41	+3.32	+0.09	+0.03	
2:00	+3.53	+3.43	+0.10	+0.03	
3:00	+3.64	+3.54	+0.10	+0.03	
4:00	+3.66	+3.56	+0.10	+0.03	
5:00	+3.67	+3.67	0.00	0.00	
6:00	+3.68	+3.68	0.00	0.00	
7:00	+3.71	+3.71	0.00	0.00	
8:00	+3.43	+3.33	+0.10	+0.03	
9:00	+1.78	+1.58	+0.20	+0.11	
10:00	-0.29	-0.59	--	--	c (see criteria table below)
11:00	-2.60	-3.28	--	--	c (see criteria table below)
12:00	-5.23	-6.27	--	--	c (see criteria table below)
13:00	-6.29	-7.33	--	--	c (see criteria table below)
14:00	-6.55	-7.76	--	--	c (see criteria table below)
15:00	-7.04	-8.06	--	--	c (see criteria table below)
16:00	-6.48	-7.41	--	--	c (see criteria table below)
17:00	-5.24	-5.98	--	--	c (see criteria table below)

Criteria for Omitting Data

a - CA & CB $<$ CS; CB $\geq$ CA
b - CA $<$ CS; CB $\leq$ CS
c - CA & CB $>$ CS; CB $\leq$ CA
d - CA $>$ CS; CB $\geq$ CS

Mean Coefficient, W = .05

FIGURE A1: DO DEFICIT DECREASE VS DEFICIT ABOVE JOHN ST. WEIR (Stn. 6)

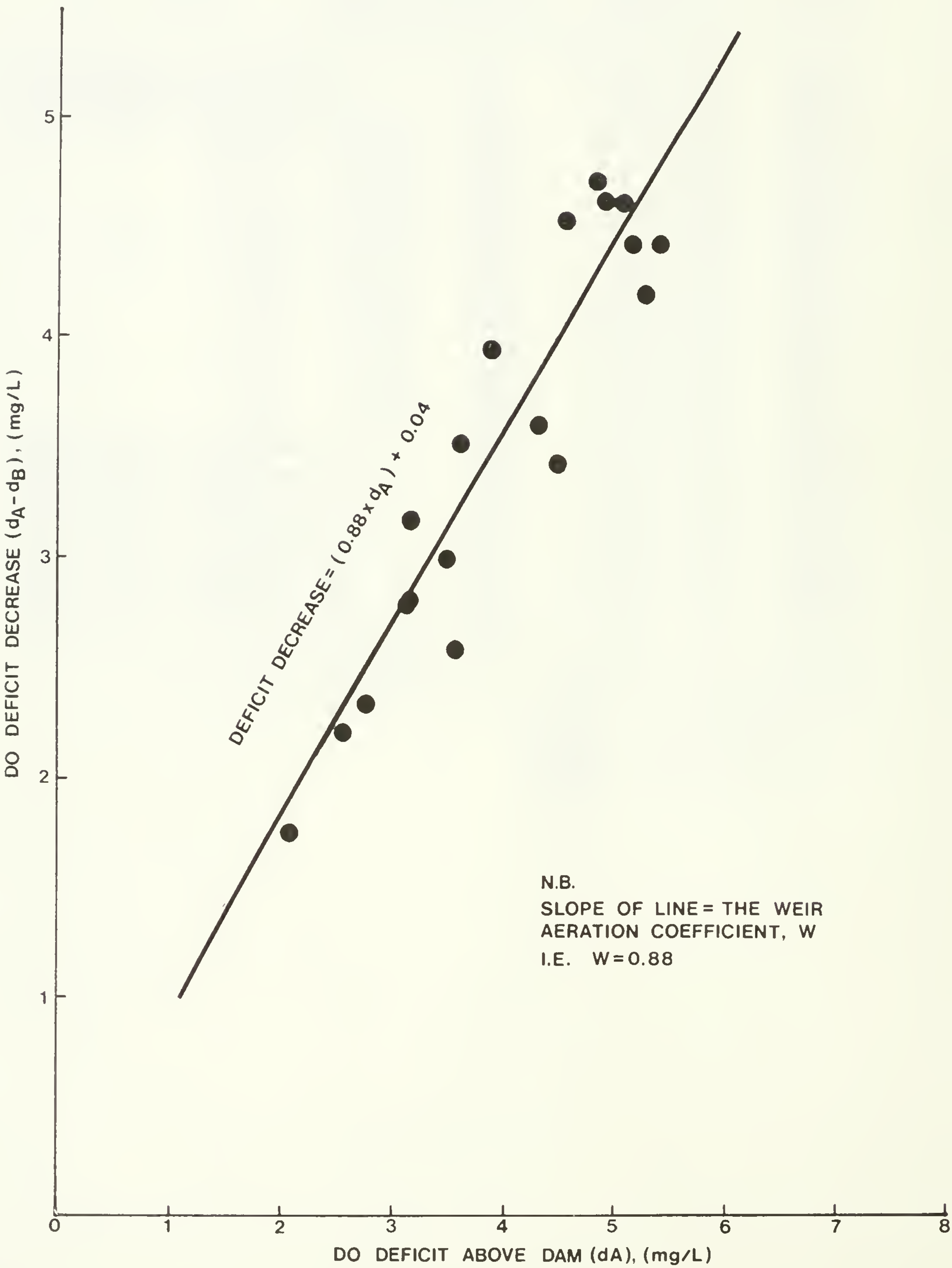


FIGURE A2 : DO DEFICIT DECREASE VS DEFICIT ABOVE DAM AT STN 10

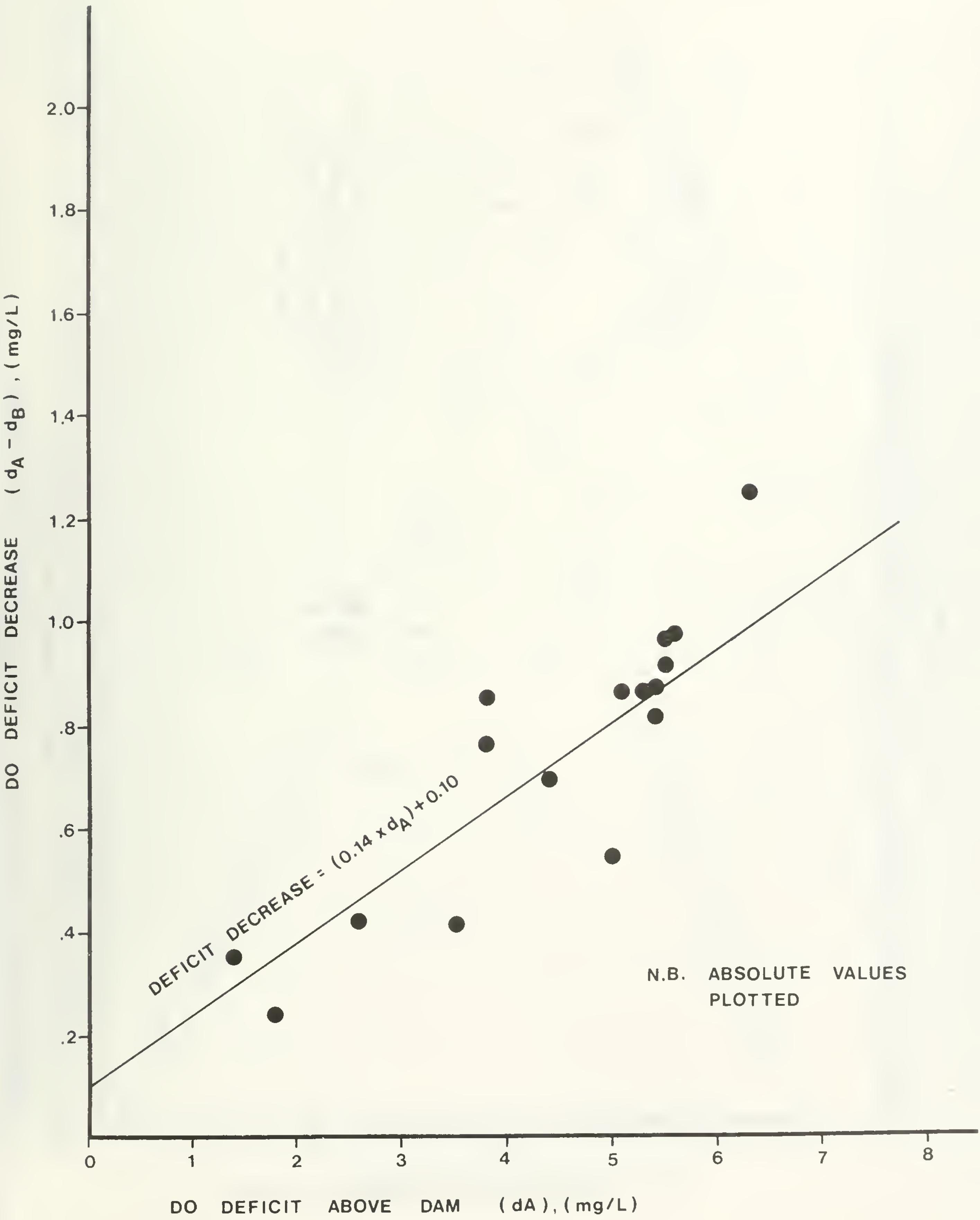


FIGURE A3: DEFICIT DECREASE VS DEFICIT ABOVE 3-STEP WEIR

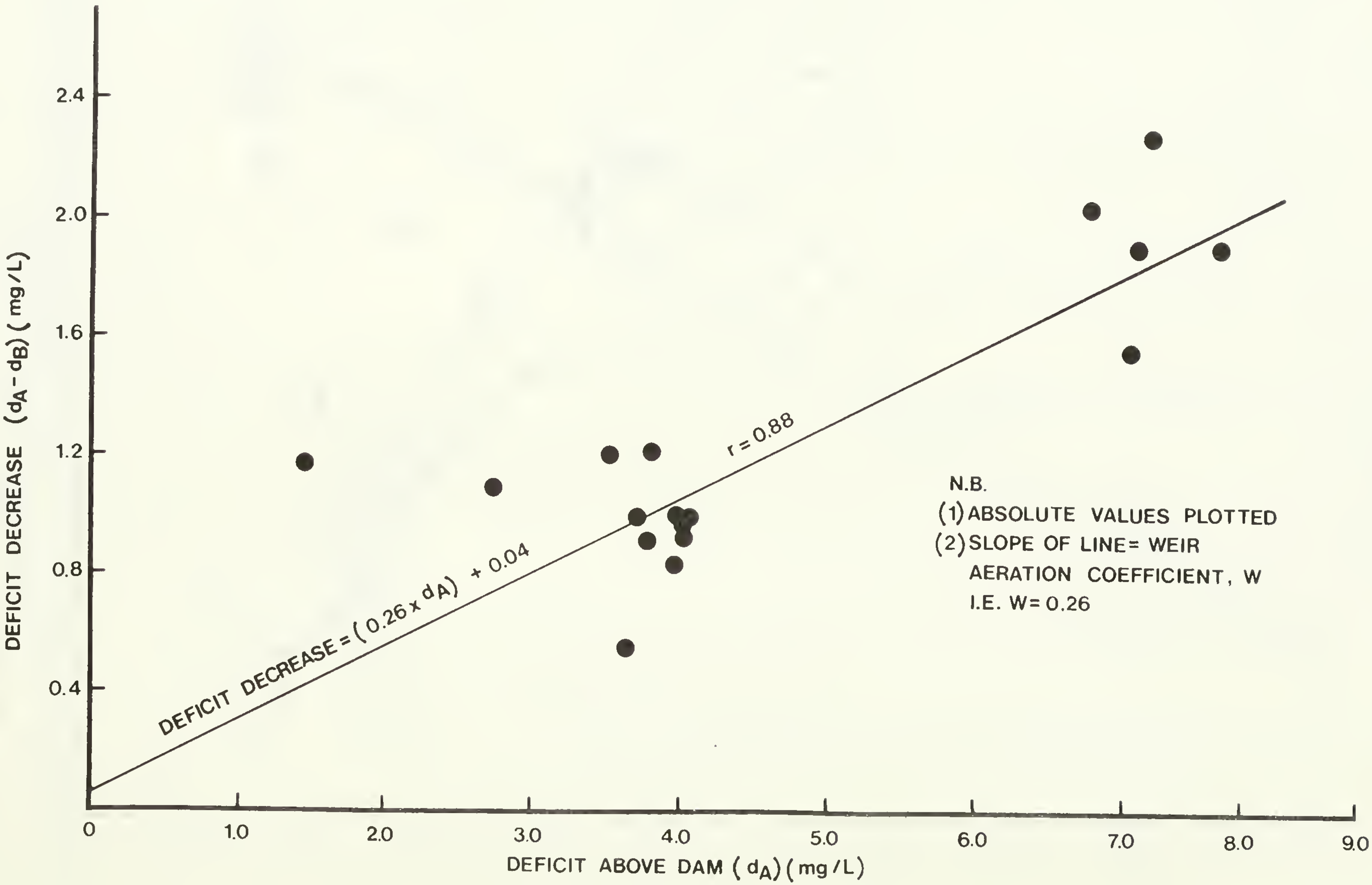


FIGURE A4: DEFICIT DECREASE VS DEFICIT ABOVE 5-STEP WEIR

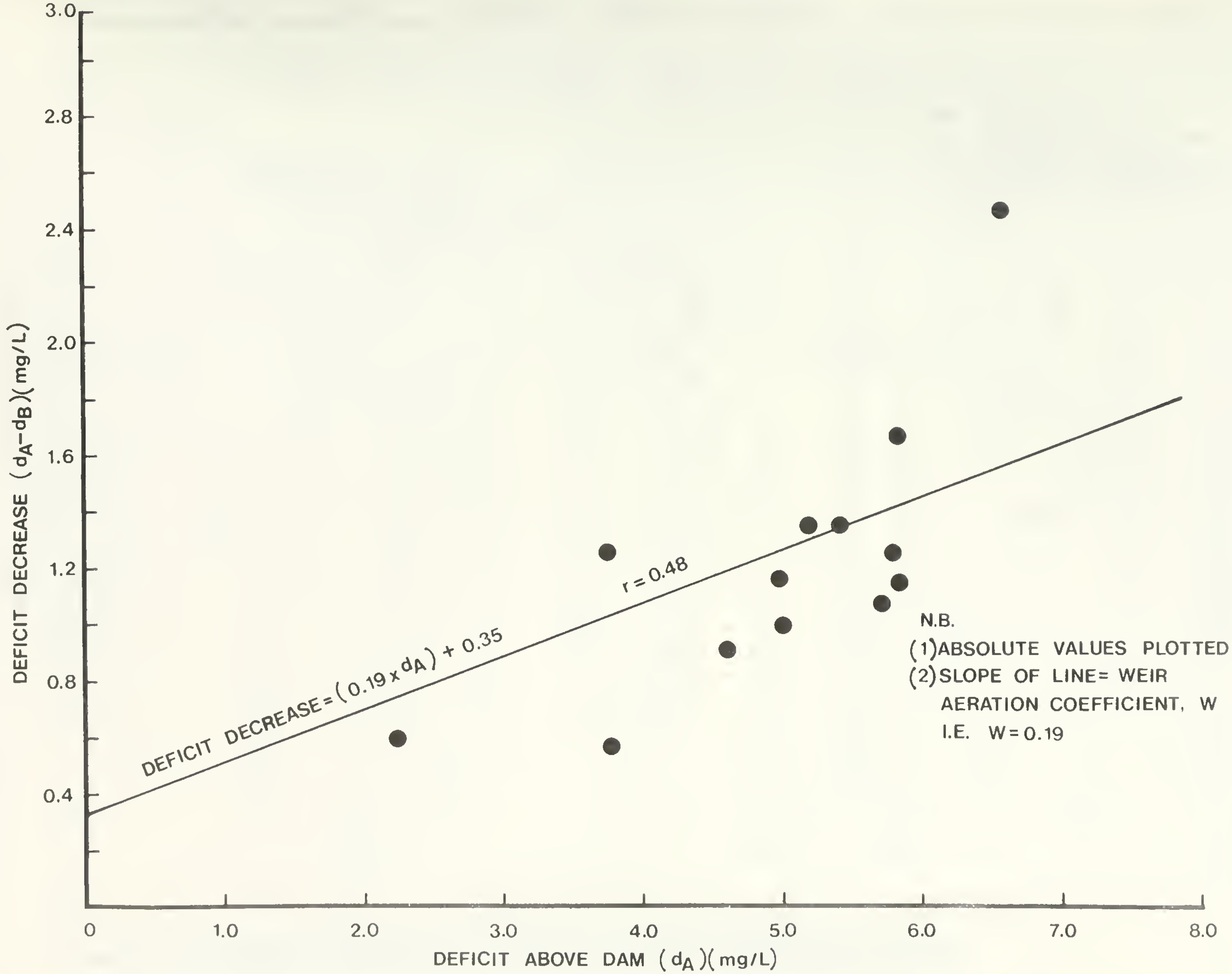
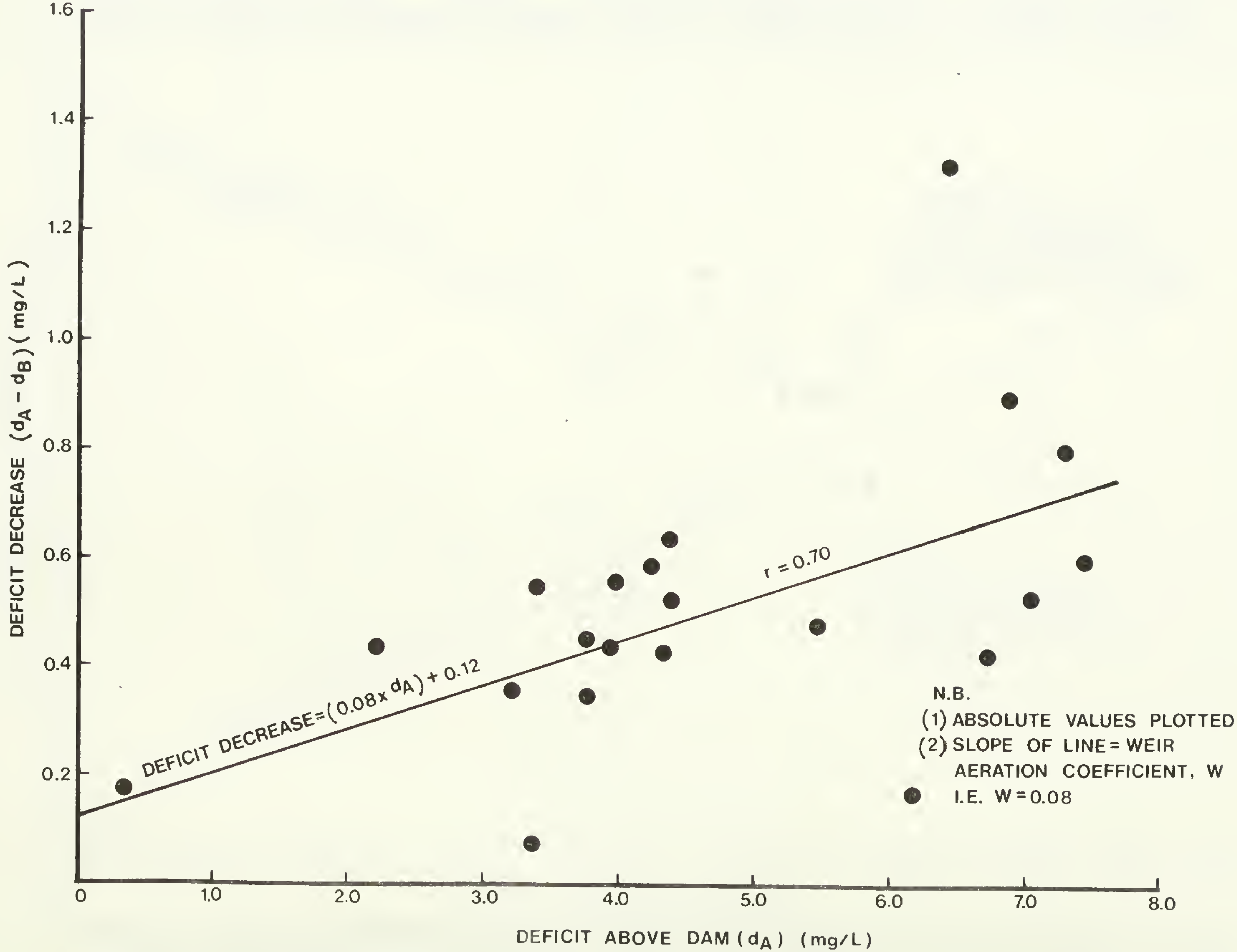


FIGURE A5: DEFICIT DECREASE VS DEFICIT ABOVE SINGLE DROP WEIR



STRATFORD-AVON RIVER ENVIRONMENTAL MANAGEMENT PROJECT
LIST OF TECHNICAL REPORTS

S-1 Impact of Stratford City Impoundments on Water Quality in the Avon River
S-2 Physical Characteristics of the Avon River
S-3 Water Quality Monitoring of the Avon River - 1980, 1981
S-4 Experimental Efforts to Inject Pure Oxygen into the Avon River
S-5 Experimental Efforts to Aerate the Avon River with Small Instream Dams
S-6 Growth of Aquatic Plants in the Avon River
S-7 Alternative Methods of Reducing Aquatic Plant Growth in the Avon River
S-8 Dispersion of the Stratford Sewage Treatment Plant Effluent into the Avon River
S-9 Avon River Instream Water Quality Modelling
S-10 Fisheries of the Avon River
S-11 Comparison of Avon River Water Quality During Wet and Dry Weather Conditions
S-12 Phosphorus Bioavailability of the Avon River
S-13 A Feasibility Study for Augmenting Avon River Flow by Ground Water
S-14 Experiments to Control Aquatic Plant Growth by Shading
S-15 Design of an Arboreal Shade Project to Control Aquatic Plant Growth

U-1 Urban Pollution Control Strategy for Stratford, Ontario - An Overview
U-2 Inflow/Infiltration Isolation Analysis
U-3 Characterization of Urban Dry Weather Loadings
U-4 Advanced Phosphorus Control at the Stratford WPCP
U-5 Municipal Experience in Inflow Control Through Removal of Household Roof Leaders
U-6 Analysis and Control of Wet Weather Sanitary Flows
U-7 Characterization and Control of Urban Runoff
U-8 Analysis of Disinfection Alternatives

R-1 Agricultural Impacts on the Avon River - An Overview
R-2 Earth Berms and Drop Inlet Structures
R-3 Demonstration of Improved Livestock and Manure Management Techniques in a Swine operation
R-4 Identification of Priority Management Areas in the Avon River
R-5 Occurrence and Control of Soil Erosion and Fluvial Sedimentation in Selected Basins of the Thames River Watershed
R-6 Open Drain Improvement
R-7 Grassed Waterway Demonstration Projects
R-8 The Controlled Access of Livestock to Open Water Courses
R-9 Physical Characteristics and Land Uses of the Avon River Drainage Basin
R-10 Stripcropping Demonstration Project
R-11 Water Quality Monitoring of Agricultural Diffuse Sources
R-12 Comparative Tillage Trials
R-13 Sediment Basin Demonstration Project
R-14 Evaluation of Tillage Demonstration Using Sediment Traps
R-15 Statistical Modelling of Instream Phosphorus
R-16 Gully Erosion Control Demonstration Project
R-17 Institutional Framework for the Control of Diffuse Agricultural Sources of Water Pollution
R-18 Cropping-Income Impacts of Management Measures to Control Soil Loss
R-19 An Intensive Water Quality Survey of Stream Cattle Access Sites